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ORIGINAL ARTICLE

Organizational Accounts of Malfunction: The Dual-Order Approach and the Normative Field Alternative

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Abstract
The notion of malfunction is critical to biological explanation. It provides a test bed for the normative character of functional attribution. Theories of biological functioning must permit traits to operate but, at the same time, be judged as malfunctioning (in some naturalized, nonarbitrary sense). Whereas malfunctioning has attracted the most attention and discussion in evolutionary etiological approaches, in systemic and organizational theories it has been less discussed. The most influential of the organizational approaches (by Saborido, Moreno, and Mossio) takes a dual-order approach to malfunctions, as a set of functions that fit first-order constitutive norms but fail to obey second-order regulatory ones. We argue that this conception is unnecessarily complicated (malfunctions do not need to arise as a result of two conflicting orders of norms) and too narrow (it excludes canonical cases of malfunctioning). We provide an alternative organizational account grounded on viability theory. The dynamics of the traits that constitute an organism define the normative field of its viability space: sugar must be replaced at a certain rate, blood must be pumped at a certain pace, and so on. A trait operates normatively when its effects on the viability space correlate positively with the normative field. Three senses of dysfunctionality might be distinguished: *subfunctional* operations are those that positively correlate with the normative field but quantitatively fail to match the required speed; *malfunctional* operations are those that do not positively correlate with the normative field; and *nonfunctional* traits either don't operate at all or operate with null effect on the normative field.

Keywords Autonomous Organization · Dysfunction · Malfunction · Natural norms · Normative field · Normative function

Introduction: No Functioning Without (Potential) Malfunctioning

A planet orbiting a star with a given period does nothing *wrong* if the orbit turns out to be unstable and doesn't match the previous regular period. In fact, the planet cannot be properly said to *do* anything; it is simply said to suffer the consequences of natural laws. The same goes for a snow crystal melting back into water, a volcanic rock rolling downhill, or a nebula expanding. However, the change of flagellar rotation in bacteria, the rhythms of your heart, or the contraction of a cheetah's ocular muscles are different. The function of flagella is to propel the bacteria, the function of the heart is to pump blood, the function of ocular movements is to fix the gaze.

Unlike nomological explanations (Hempel and Oppenheim 1948), functional ones are normative in two broad senses: (a) a process or trait can satisfy or fail to satisfy a norm (*valence*) and (b) it can function better or worse (*degree*). In McLaughlin's words:

> If things of a particular type have a function, then some of them may perform this function better or worse than others do. Wherever we can speak sensibly of better and worse, we are introducing not just an ordering relation among things but also an evaluation of this ordering relation. (McLaughlin 2009, p. 93)

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Surely the orbit of a planet might serve a purpose for the European Space Agency; for example, to direct a spacecraft towards a comet. We can rightly say that the orbit better or worse serves a function within that project. But this is an instrumental attribution, alien to the very object (planet) or process (orbiting) of which the function is predicated and its systemic context (e.g., the solar system). *Natural functions*, instead, are somewhat intrinsic[1] to the entity to which the function is predicated. Burge defines it as follows:

> [a natural function is] a level of performance that is adequate to fulfill a function or a purposiveness, and that constitutes an explanatory relevant kind, independently of any individual's having a positive or negative attitude toward the function or the norm […] it is a priori that for every function there are natural norms in this sense. (Burge 2009, p. 269)

There is no function if there is no room for failure or possibility of malfunctioning, otherwise the notion of function would add nothing to the mere description of a process. Thus, the notion of malfunction is critical to functional explanations of biological systems for it provides a test bed for the normative character of functional attribution. Under some circumstances theories of biological functioning must permit that traits operate, but at the same time be characterized or judged as malfunctioning (in some naturalized, nonarbitrary sense).

In fact, the way in which malfunctioning is defined and analyzed as an epistemic category deeply determines the full scope of functional analysis. It carries consequences. In a sense, it is malfunctioning (actual or potential, compensated or catastrophic) that determines the functional nature of a trait or process and the very value of functional explanation. The relationship between how a process unfolds (or a trait operates) and the norm that it serves (as a reference for functional analysis) is what malfunctioning reveals. It is against the background of the various ways in which a trait could malfunction that its proper functioning is constituted. Furthermore, in some accounts, it is only because I am not malfunctioning that I am functioning correctly, or, to put it differently, "whatever is not dysfunctional is functional."[2]

There have been different accounts of normative functioning that, in turn, involve different accounts of what proper functioning and malfunctioning requires. The organizational approach to function and malfunction that is the object of this article confronts two broad schools of thought that try to naturalize the concept of function.[3] The biostatistical (Boorse 1977) approach, which is widespread in philosophy of medicine and health, states that functional and dysfunctional traits are to be distinguished in comparison with the average typical functioning of the same kind of trait in members of the same reference class (e.g., same species, age, and sex). A trait is malfunctional or dysfunctional, according to this view, if it deviates from this statistically typical or normal functioning. On the other hand, the evolutionary, etiological, or "selected-effects" approach to functions (Wright 1976; Millikan 1989; Neander 1991; Garson 2016) focuses instead on the way in which evolution has shaped biological traits. As Karen Neander put it: "Roughly speaking, a biological part functions properly [normatively] when it can do what it was selected for and malfunctions when it cannot" (Neander 1995, p. 111).

The benefits and problems of biostatistical and etiological approaches to (mal)function have been debated at length (Davies 2000; McLaughlin 2001; Christensen and Bickhard 2002; Saborido 2011; Garson 2016). A central criticism that has been made of both biostatistical and evolutionary approaches is that they appear to presuppose a notion of function in order to explain why a trait has been selected or why it is prevalent in a population,[4] thereby introducing a risk of circularity (see García-Valdecasas and Deacon 2024; Rama 2025). Also, both approaches can be said to suffer severe

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[1] We here follow Jonas's distinction between intrinsic and extrinsic purposefulness (1953) and Searle's distinction between intrinsic intentionality and extrinsic or derived intentionality (1983). Natural functions can be said to be intrinsic as opposed to artificial functions that are considered extrinsic. We say that natural functions are *intrinsic* in the sense that they arise from the inner organization of a system and its capacity for self-guided or self-modulated coupling with the environment. In contrast, *extrinsic* functions, such as those attributed to artifacts, are defined by an external socio-technical context of design, use, and repair. In the absence of this context, artifacts lose their functional attribution, which ultimately depends on other autonomous systems that normatively evaluate and regulate their attributed functionality. Both, intrinsic and extrinsic functionality, have relational aspects. How organisms and artifacts are coupled to their environment is essential to properly understand them. In the case of organisms, however, this relationship, and particularly its normative dimension, is constituted and stirred from within. In artifacts, to the contrary, the relationship with the environment, despite being often active, is devoid of a normative dimension that is provided by the artifact itself, and is sustained instead by its socio-technical environment. Although this distinction might be partially blurred: artifacts might ultimately be considered to have intrinsic functions within a wider socio-technical form of life (but we won't pursue this elaboration here).

[2] We shall come to this point at the end of the article. Till then we are going to use the terms dysfunction and malfunction (and derivatives: dysfunctional, malfunctioning, etc.) interchangeably.

[3] There are other approaches to functionality, among them, most notably, the dispositional account (Cummins 1975; Mills and Beatty 1979; Bigelow and Pargetter 1987). However, we have left this family of functional explanations out of this short introduction, because they have shown difficulties in addressing dysfunctionality and proper or normative functionality (see Conley 2023 for a contemporary update).

[4] Note that both approaches can be said to share a common dependence on statistical prevalence: in a sense, the definition of a selected trait is none other than its statistical prevalence in the population (Rama 2023).

difficulties in providing insights on the emergence of novel functions. Whereas a new trait, according to these theories, should qualify as nonfunctional or dysfunctional, either because it is statistically rare or because it hasn't been selected (yet), the newly arising trait could, nevertheless, make harmonious and beneficial contributions to the well-being of the organism. Moreover, normative functional judgment would be impossible for organisms of which no historical or population-level comparative records exist. This objection is connected to the lack of organism-centered criteria to define normative functionality, a situation that has raised epiphenomenalist criticisms (Christensen and Bickhard 2002): both evolutionary history and comparative statistical properties are not causally efficacious within the current organization of a system, so normative function could provide no causally relevant explanatory value to the actual functioning of an organism. In addition, many traits do not arise as a result of natural selection but emerge from structural or self-organized inherent properties of organisms which would seem to preclude, according to selected-effects theories, their possessing normative functions (Kauffman 1993; Newman 2023).

Contrary to etiological and biostatistical accounts, the organizational approach focuses on the specific processes and relationships (operations, dependencies, constraints, coordinations, etc.) that constitute the system of which functional or dysfunctional traits are predicated. By doing so, it tries to avoid some of the problems that other naturalist approaches have been shown to suffer. In this article I shall focus on the organizational account of (mal)function. The core idea of this article is that *dysfunctions can be understood as a failure of a trait to make the necessary contribution (at the required pace or direction) to the generation and maintenance of the system's viability over time*, *in the manner that is dynamically presupposed by other traits belonging to the system and contributing to its maintenance*. First, I shall provide first a general overview. Next, I will focus on the most salient and elaborated of the organizational accounts of malfunction by Saborido, Moreno, and Mossio. I identify a number of problems with their approach and make explicit some of the assumptions underlying them. I then propose an alternative approach, the normative field approach, based on viability theory. I finish with a comparison between the two organizational approaches and the limits and potential development of the normative field approach.

Organizational Approaches to Autonomous Normative Functions

It is possible to trace the organizational approach back to Aristotle's biology, Kant's conception of living self-organization in his *Critique of Judgment*, German idealism, and the organicists Bernard (1865), Cannon (1932), Goldstein (1939), Russell (1945), Canguilhem (1966), Piaget (1969), and Jonas (1965, 1966, 1968). Systems theory (Bertalanffy 1969) and cybernetics (Ashby 1952, 1957) provided operational frameworks to develop more detailed and naturalized approaches to organicism. More recently, autopoietic or enactive (Varela et al. 1991; Stewart et al. 2010; Weber and Varela 2002; Di Paolo and Thompson 2014) and complex systems approaches to theoretical biology and philosophy of biology (Kauffman 2000, 2003; Bechtel and Richardson 2010; Moreno et al. 2011; Capra and Luisi 2014; Mossio and Bich 2017) have further developed this trend.

Ever since the explicit development of a theory of normative function in the context of contemporary philosophy of biology (Schlosser 1998; McLaughlin 2001; Christensen and Bickhard 2002; Mossio et al. 2009) the so-called systemic or *organizational account* of normative function has gained momentum and recognition (see Allen and Neal 2020; Garson 2016 for a general overview). Broadly speaking, for the organizational or autonomous account of normative function (Bickhard 2000; Collier 2000; Barandiaran 2002; Christensen and Bickhard 2002; Bechtel 2007; Mossio et al. 2009; Christensen 2012; Barandiaran and Egbert 2014; Moreno and Mossio 2015) norms emerge from dynamic presuppositions between the operations of component parts or traits (more on this latter).

The notion of a self-maintaining organization of autonomous systems is central to this account. The departure point is to observe that there are basically two types of cohesion or systemic consistency that permit an entity to be individuated: conservative and dissipative structures. In conservative structures (e.g., tables, rocks, or stars) raw physical forces like chemical bonds or gravity lump components together. One needs to add external energy to destroy the system. Dissipative structures (vortex, bacteria, dogs), on the contrary, need external energy and matter to keep an emergent structure stable across a continuous flow (Nicolis and Prigogine 1977): the structure of the system is (at least partly) the result of its far-from-equilibrium activity. Some dissipative structures are highly organized and display self-producing capacities by which the very constituents of the system (its parts) are a physicochemical product of the system they compose, and they coordinate so as to maintain the system as a whole while distinguishing themselves from their environments (Maturana and Varela 1980).

Not any kind of closure, or self-sustaining process circularity, qualifies for genuine autonomy. As Bickhard (2000) notes, autonomous system needs to be *recursively* self-maintaining. This additional requirement is often put in place to distinguish biological autonomous systems from spontaneous dissipative or self-organized systems (like Benard cells, reaction diffusion spots, tornadoes, etc.). This level of recursivity can be captured through the notion of constraint (Ruiz-Mirazo and Moreno 1998; Kauffman 2000; Umerez and Mossio 2013). In addition to being constituted by a circular, self-sustaining, causal network, for a system to be considered an autonomous organization, it is also required that it be the result of a set of constraints that are both the product of the self-sustaining network and that exert a constraining action over its activity. So, it has been argued, for the system to achieve organizational closure it needs to achieve *constraint closure*: at least a set of such constraints must have the property that each constraint needs to depend on some other constraint and enable at least another one (Mossio and Moreno 2010; Montévil and Mossio 2015). The canonical example of a constraint in a minimal biological organization is a catalytic enzyme. It modulates a reaction rate without being itself transformed on that reaction. In turn, it is produced by the organism though the effect of other constraints (including other enzymes) and it contributes to the self-maintenance of the whole. Whether it is characterized through constraint closure or other forms of recursive self-maintenance, autonomy is considered a fundamental principle of living systems (Varela 1979; Moreno and Mossio 2015). At the cellular level, chemical components (proteins, ATP, etc.) and their complex arrangements (membranes, organelles, microtubules, etc.) are (mostly) produced and repaired by the very activity of the system. At the multicellular scale, different organs and systems (e.g., circulatory, respiratory, and digestive systems) contribute to the material production of the organs composing the system.

The canonical contemporary formulation of normative functionality within this tradition can be traced back to Christensen and Bickhard: “Functions are essentially relations, and these process interdependency relations are what determine the nature of organisms as viable (cohesive) systems. Individual parts and processes serve normative functions within autonomous systems because of the way they satisfy the requirements of other processes within the system,” (Christensen and Bickhard 2002, p. 19).

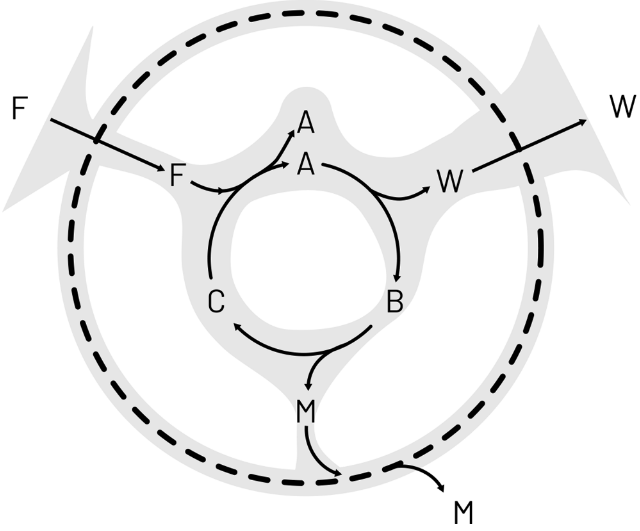

Fig. 1 Minimal functional diagram of a self-producing and self-maintaining system composed of metabolites A, B, and C, organized in a self-producing loop fed by food molecules F and generating a waste product W, while producing a membrane molecule M that encapsulates the whole system and constraints food inflow and waste outflow

There are different elaborations of this account but let me provide a basic, clear, and concise one:

- If B and C *dynamically presuppose* A it means that their operations would be severely modified and ultimately their existence compromised were A to operate differently or cease to operate, in virtue of A, B, C composing a recursively self-maintaining system.
- The *normative function* of a trait or process A is to operate according to the dynamic presupposition of other traits (B, C,…) within a recursively self-maintaining organization.

A concrete example might help illustrate the general definition provided above (see Fig. 1). An autocatalytic cycle is composed of $A\rightarrow B+W$, $B\rightarrow C+M$, and $C+F\rightarrow 2A$. Metabolites A, B, and C produce themselves in a circular fashion by means of food F intake and waste output W while producing membrane M molecules that self-assemble encapsulating the reaction network. This is the basic minimal model of (proto-)cellular organization, according to autopoietic theory (Varela et al. 1974; Maturana and Varela 1980; Luisi 2006;), basic autonomous systems theory (Ruiz-Mirazo and Mavelli 2008; Ruiz-Mirazo and Moreno 2012), the chemoton model (Gánti 2003) and some basic implementations of M-R systems (Piedrafita et al. 2010); see also Bechtel (Bechtel 2007) for an overview.[5]

Within this organization, component parts or traits A, B, and C and their specific concentrations dynamically presuppose the “right” concentration of the other components and the specific reaction rates. Metabolite B functions (operates normatively) when its concentration and reaction rates match the dynamic presupposition of the rest of components for the self-maintenance of the organization. So,

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[5] On the minimal model presented above, constraint closure could be illustrated by adding arrows of constraining influence of metabolites as catalysts of other reactions: A would catalyze the reaction $B\rightarrow C+M$, B would catalyze $C+F\rightarrow 2$ A, and C would catalyze $A\rightarrow B+W$. We have avoided including this level of complexification because it adds little to the dynamic definition of normativity and malfunction, but also because both the food F intake and the membrane operate as constraints (or boundary conditions) that could perfectly be said to emerge from a more elaborate closed network of constraints so that the relationship between a self-sustaining network of processes (auto-catalytic reaction cycle) and a set of self-generated constraints is sufficiently well captured by this minimalist setup for the purpose of this article.

for instance, B needs to produce M at a certain rate for the membrane to grow or replace decaying M molecules at the speed required to avoid bursting or disintegration. M molecules, in turn, need to control the inflow of F at a rate sufficiently slow to avoid bursting but sufficiently fast to avoid the A→B→C→A reaction running down, and so forth in a circular manner.[6]

The *Dual-Order* Approach to Malfunction

Unravelling the Dual-Order Approach

What might be called the *standard* organizational approach to biological malfunction (Mossio et al. 2009; Moreno and Mossio 2015), or at least the one that has recently attracted most attention (Garson 2016, 2017; Cusimano and Sterner 2019; Allen and Neal 2020), takes a dual-order approach.[7]

This approach to malfunction has developed into theories of health and medicine (Saborido and Moreno 2015; Saborido et al. 2016), applications in social-ecological systems (Nunes-Neto et al. 2016) and, more recently, in moral and ethical philosophy (Moosavi 2019). Saborido (2011) and later Mossio and Moreno (2015) provide an organizational account of biological function in which: “malfunctions are a subset of functions that fit first-order norms (of the first-order ongoing organization in which they match functional presuppositions), but not second-order ones (since they do not obey to second-order regulatory functions, and prevent the shift to another first-order organization)” (Moreno and Mossio 2015, p. 85).[8]

As a canonical example they provide only the case of a coronary artery’s malfunctioning:

> Suppose that, in some circumstances, a regulatory mechanism is triggered to shift an organism from a given regime of self-maintenance to a different one. For instance, the autonomic nervous system (the regulatory subsystem, in this case), in a situation of danger, can send signals to move from a regime “at rest” to another one “under stress” in which the organism runs. Suppose also that, for some structural reason, one functional part of the organism does not modulate its activity and, as a consequence, it is unable to match the functional presuppositions of the regime induced by the regulatory functions. For instance, the coronary artery might not be able to increase its diameter sufficiently to match the higher rate of blood flow pumped by the heart: as a consequence, its range of activity is not in accordance with the functional presuppositions of the other functional traits and organs in this specific circumstances. (Moreno and Mossio 2015, p. 84)

I shall name this the “SMM” (for the initials of the contributing authors) or the “dual-order” explanation because it requires two orders of norms (constitutive and regulatory) to deliver an account of malfunctioning. The constitutive order is generally understood to be the productive or self-maintaining functional network, like the minimal one we depicted previously. The metabolic network plus membrane inflow and outflow dynamics is a paradigmatic case, as are the physiological networks of digestion, blood circulation, respiration, and so on. The dual-order approach considers that this produces first-order norms. The regulatory order is the second one (although higher orders are in principle possible: regulations of regulations, etc.). The regulatory order implies modulations of the lower constitutive order, and SMM consider they give rise to second-order norms. Examples of regulatory processes are the activation of certain genes to initiate new metabolic pathways (Barandiaran and Moreno 2008; Bich et al. 2016), or the opening of molecular channels in the membrane (Ruiz-Mirazo and Mavelli 2008), hormones regulating heart rhythms or embodied neurodynamic processes mediating foraging. As a first approximation it seems like first-order norms should already imply a sense of potential malfunctioning but the dual-order approach demands instead a specific interplay between the two orders, together with a shift between regimes of self-maintenance. A regime of self-maintenance is one in which a certain combination of processes and rates is necessary to maintain the system. A cell might be able to survive under different conditions, some of

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[6] We are leaving many fundamental aspects of basic or minimal autonomous systems out of this picture like work-constraint cycles, material self-assembling properties, genetic or nonreactive components, energy currencies, gradients and membrane potentials, collective effects, reproduction, etc. Although these and other components and principles are essential for a full characterization of life (Ruiz-Mirazo et al. 2004) the minimal essential components are in place to provide a minimal model that can clarify and instantiate the required conceptual resources to explain normative function and dysfunction.

[7] Other proponents of the organizational account have made a much more superficial (if any) treatment of malfunction or dysfunctionality.

[8] In Moreno and Mossio (2015) at least three different definitions of malfunction are provided. The other two (similar to the one I have chosen as a target definition) are: “If, because of some structural defect, a particular trait (1) does not modulate its activity in spite of the triggering of a regulatory mechanism and (2) as consequence, it is unable to operate within the admissible range determined by some of the regimes of self-maintenance among which regulation governs the shifts, then the trait malfunctions in organisational terms” (pp. 83–84); and, “In these specific situations, in which an unresponsive trait does not modulate its activity as required by the intervention of regulatory functions and therefore prevents adaptive regulation to shift to a different first-order organisational regime, so that the whole system can only remain in a specific organisational regime in which the trait match the functional presuppositions, that trait is malfunctional ” (p. 84).

which might demand that specific organizational changes take place: for example, a change of metabolic pathways to metabolize lactose or glucose.

We can now get back to SMM's definition to unfold it in more understandable terms.

1. Given traits T_1 (lower first-order constitutive process) and T_2 (higher second-order regulatory process), and regimes of self-maintenance Ra, where T_1 normatively functions within ranges (a_1, a_2), and Rb, where T_1 functions normatively within range (b_1, b_2):
2. T_1 malfunctions if and only if T_2 regulates T_1 to switch from regime Ra → Rb and T_1 fails to match new range (b_1, b_2).

We can now go back to the heart example proposed by Moreno and Mossio. The coronary artery (T_1) malfunctions if and only if the adrenal gland (T_2) releases adrenaline increasing the heart rate to switch from the regime "relax" to regime "under-stress" (Ra→Rb), and the coronary artery (T_1) fails to increase its diameter within the new range (b_1, b_2) necessary for adrenaline to take the presupposed effect.

In order to further clarify the dual-order approach to malfunctioning we can slightly complexify the minimal model presented before (see Fig. 1) and complement it with the possibility of a second metabolic pathway. Consider that, together with F molecules, the system can also feed on lactose molecules L. An additional mechanism could exist that switches to a new metabolic pathway capable of metabolizing L in the absence of F.[9] A minimal case of the dual-order approach would require that at least two regimes of self-maintenance exist (e.g., two alternative metabolic pathways—say a new metabolic pathway $A \rightarrow B + W$, $B \rightarrow D + M$, and $D + L \rightarrow 2A$) regulated by an additional mechanism E (e.g., a genetic expression that synthesizes an enzyme that facilitates reactions $B \rightarrow D + M$ and $D + L \rightarrow 2A$). We would thus have a self-maintaining regime Ra constituted by the cycle A-B-C-A and a regime Rb constituted by A-B-D-A. So, for the dual-order approach, $B \rightarrow D + M$ (T_1) would malfunction if and only if E regulates T_1 to switch to the new regime A-B-D-A, and T_1 fails to match the range of production of D or M required for the self-maintenance of the system.

Problems with the Dual-Order Approach

I shall now argue that the SMM approach is both *too narrow* (it leaves out important cases of malfunctioning) and *unnecessarily complicated* (a simpler formulation can account for these and more cases of malfunctioning).

It is too narrow because it excludes a number of typical cases for which we want to keep the notion of malfunction:

1. *Cases of malfunctioning within a specific self-maintaining regime*. Within Ra, T_1 might be operating within ranges (b_1, b_2) or simply out of the range (a_1, a_2). These cases cannot be considered malfunctions by SMM's definition.[10] So, for example, if the coronary artery loses flexibility and its diameter reduces flow (with deleterious consequences in the mid term) it cannot be said to malfunction within the "at rest" regime.
2. *Cases of malfunctioning of (higher-order) regulations*. The definition leaves out cases in which it is the higher- (or ultimately highest-) order regulation that fails. If an enzyme fails to regulate a metabolic pathway, according to SMM's definition it cannot be said to malfunction unless a higher-order regulatory mechanism exists that in turn switches to a new regime.[11] Recall that it is only to T_1 that malfunctioning can be attributed. The autonomic nervous system cannot be said to malfunction if it doesn't trigger the "stress" response under dangerous situations.

It follows that in general it is impossible, according to the SMM definition, to distinguish between malfunctioning of T_1 and T_2. It could perfectly be the case that T_2 is malfunctioning in not being able to shift T_1's range, and not T_1's failure to match the new range. There are more complicated cases that are left out of a proper malfunctional characterization but it should be clear by now that SMM's definition is too narrow. It is also unnecessarily complicated: a simpler characterization of malfunction can account for the cases covered by SMM and those excluded from their definition. We have briefly sketched it previously and I will provide a more detailed elaboration in the next section.

So why did SMM choose this approach to malfunction? There are two major assumptions that force the complicated

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[9] In fact, Moreno and Mossio (2015; Sect. 1.8.2, p. 33) take this lac-operon type of switch as a paradigmatic example of regulatory process. Unfortunately they don't come back to this example for their interpretation of malfunction.

[10] It could be argued that T_1, operating in range (a_1,a_2), is the result or the demand of a previous regulation (ultimately developmental) of some T_2'. But SMM's definition requires not only that a regulatory mechanism shifts regimes but also that T_1 "fit first-order norms (of the first-order ongoing organization in which they match functional presuppositions)." It is these norms that T_1 might fail to satisfy in the first place so as to be considered as malfunctioning, and SMM's formulation prevents it.

[11] The situation can worsen if one considers that closure of second-order constraints could preclude the emergence of higher orders (I thank a reviewer for pointing this out) or, similarly, if a biological control mechanism cannot be properly understood as organized in hierarchical levels but displays instead an inherent heterarchical organization (Bechtel 2022). In both cases malfunctions could never be attributed to higher order or regulatory traits.

definition we have just analyzed: (1) First-order (constitutive) norms are all or nothing, gradual norms are to be found somewhere else. (2) Regulations occur (only) as switches between regimes of self-maintenance.

The first is a classical assumption based on the premise that life is an all-or-nothing property (you are either alive or dead) or that a trait has either been selected or has not, without admitting degrees, thus turning functionality into a binary property (either you have it or you don't). This assumption is explicit when Moreno and Mossio say that: "While *functions are all-or-nothing* concepts (a trait is either functional or nonfunctional), malfunctions admit degrees and a given trait can contribute more or less well (or poorly) to the maintenance of the organisation" (Moreno and Mossio 2015, p. 83; italics added). However, nothing prevents functions from being gradually achieved.[12] As we shall see later, this gradation can be conceived either negatively (in relation to the distance, and derivatives, to viability limits) or positively (in terms of distances, and derivatives, to well-being or optimal set points or trajectories). In other words, dynamic presuppositions can be conceived as having *gradients*. Trait A can be dynamically presupposed not simply as functioning within a certain range but also within a certain gradient. Otherwise, notions of biological stress, relaxation, danger, plenitude, excess, decay, or medical terms like bradycardia, dyspnea, hypoxia, would make no sense for they rely, one way or another, on functions being fulfilled at a certain pace in reference to which gradations are possible before nonfunctioning is predicated.

Another assumption has to do with SMM's conception that regulations occur (only) as shifts between regimes of self-maintenance: "[regulations] do not contribute to the maintenance of closure in stable conditions (while constitutive ones do) but, when closure is being disrupted, they govern the transition towards its re-establishment (while constitutive ones do not)" (Moreno and Mossio 2015, p. 33). This assumption is in turn a combination of the bipartite distinction between constitutive dynamics and regulatory mechanisms and the binary status of functional attribution we just mentioned. When regulatory mechanisms intervene on the basic constitutive dynamics of the system, it is assumed, the system must move to a new regime: there is a qualitative change to a new mode of fulfilling self-maintenance. The theory leaves no room for a trait to function better or worse within the same regime (it either functions or it doesn't), so a change of regime is required for the old functioning to be still somewhat functional but wrong. The mechanism, thus, operates like a switch between qualitatively distinct regimes where traits can or cannot be said to operate functionally.

But if we pay attention to the way in which regulatory language is used in both cellular dynamic analysis and in multicellular physiology, regulations occur all the time without shifting or producing qualitative changes of regimes. Enzymes do not always (in fact rarely) operate as all-or-nothing switches between alternative metabolic pathways like lac-operon. Enzymatic regulation is often a regulation of rates, like glycolysis regulation where different regulatory enzymes are always present but increase and decrease their concentration in continuous modulation of metabolic processes. Similarly, hormones are rarely fully "activated" or "deactivated"; instead, their concentrations increase or decrease gradually according to various circumstances. The same goes for cardiac regulation; SMM provide the example of an organism entering a state of "danger" and moving from a state of "rest" to one of "stress" thus changing qualitative regimes. However, we are rarely fully at rest or fully in stress; and our heart is continuously regulated to satisfy varying demands of the body, modulated up and down in a gradual, nonbinary, fashion.

A Normative Field Approach to Malfunction

Graduality and Functionality

I now want to sketch out an alternative organizational theory of normative function and malfunction based on my previous work with Matthew Egbert (Barandiaran and Egbert 2014). As noted above, according to the organizational approach, norms emerge out of dynamic presuppositions between the traits or processes that compose a self-maintaining organization. As we saw, traits must operate within certain ranges for the system to persist. The problem here is that in a first approximation (both historical and conceptual) there is a lack of gradation. The whole system and/or its traits either operate within the range or do not. You are either alive or you are not. You are doing OK until you die. There is no wrong that is not immediate death. Under this framework (unless one takes additional theoretical elaborations such as the dual-order approach), malfunctioning is simply impossible: while you are alive your parts are functioning, when you are dead they aren't. So, if we are to make room for the concept of malfunctioning and those of adaptivity and agency (Di Paolo 2005; Barandiaran and Moreno 2008; Barandiaran and Egbert 2014;) we need to introduce some notion of gradation. But first it is convenient to introduce the notion of essential variables, viability space, and viable region.

Essential or critical variables are those that define the viability of a system (Ashby 1952), ultimately defining the critical dynamic presuppositions and the norms that the system

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[12] For a different approach to the graduality of normative functions see also the work of Matthewson (2020) or Šustar and Brzović (2025).

and its parts must obey in order to survive. The viability space is defined by the multidimensional space of all essential variables. Within this space, a *viable region* is defined as a subspace where, once the system enters, it can maintain itself indefinitely under stable conditions. This region represents a "safe zone," where the system remains functional as long as external disruptions are absent. For example, in relation to temperature, pressure, or oxygen levels a viable region can be defined as a range within which the system, ceteris paribus, will remain alive. These magnitudes and ranges can also be internal: oxygen intake, heart rate, and so on. But we can also define a *precarious region* where the system is (still) alive but will inevitably die if no parametric change occurs. By parametric change here we mean that the system is (assumed to be) temporarily determined by the unfolding for a set of variables (e.g., metabolite concentrations, etc.) governed by a set of parameters (e.g., reaction rates, or a set of physiological flows). For each point in the precarious region there is a minimal behavior/regulation necessary for survival (a more detailed characterization and a model will be provided below).

Normative Field and Normative Function

A *normative field* can be defined as the minimum constant parametric change, for each point of the precarious region, necessary to avoid the irreversible disintegration of the system.[13] For instance, a new enzyme (or more of an existing one) needs to be synthesized in order to increase the reaction rate of a given metabolite whose low concentration can compromise the system, or an increase in heart rate is necessary to increase oxygen to avoid systemic collapse. In dynamical systems approaches (Haken 1978; Kelso 1995) this parameter is often called the *control parameter*, since, ceteris paribus, the dynamics of the other variables are modulated by it. Within this context such parametric changes might cover what SMM call *constraints*. Since living systems are far from thermodynamic equilibrium systems, keeping a parameter or control variable (or any other) stable or constant is often something that requires active regulation: for instance, active pumping, movement, breathing, and so on. We can now, paraphrasing Barandiaran and Egbert (2014, p. 20), say that *a trait operates normatively (or functions properly) when its operations positively correlate with the normative field.*

The normative field approach works by fixing a parameter P under study, a constraint to which a normative functional attribution is to be assigned, and studying the dynamic of the rest of the system. The normative field is defined by the "intrinsic" dynamics of the system without the parameter P (or for a fixed parametric value). If another parameter Q is under normative evaluation, P's operations will be included on the "intrinsic" dynamics of the system and then it could become part of the normative field.

At the individual scale of analysis (one trait, constraint, or control parameter), only the minimum constant change is normatively mandatory; more change or a virtuous combination of various changes of other parameters could also be effective, or could benefit the organism, but are not strictly required. Normative in this sense involves what *needs* to happen, a *must*, a *requirement.* This is expressed as a minimum change. You can eat more than what your body needs, but there is only a certain minimum amount that you *need* to eat, that you *must* eat. Following this example, it is also possible that the organism becomes viable by a combination of reducing metabolic activity, slow breathing, and low food intake. This is a combination of parametric changes and only the right combination can guarantee that a very low food intake is viable. But again, it is the minimum constant food intake, minimum activity, and minimum breathing that determine the normative field.

It is also important to consider the implication of the "constant change" part that defines the normative field. Again, the example of food intake can help clarify the issue. Imagine an organism that had not had any food for some time and is currently having none: it needs to eat to avoid death. How much is mandatory for the organism to eat? According to the normative vector field approach, we first need to calculate how long the organism can stay without any food intake before dying, and then compute how fast (ceteris paribus) it should start eating right now so as to avoid death by starvation in the future. If the organism is far away from starvation it only needs to slowly start increasing food intake. If it is proximal to starvation it might have to start increasing food intake much faster.

The normative field specifies, for any point in the viability space (e.g., food reserves and current food intake), the minimum food intake rate that needs to be induced at that point so that, keeping it constant, would bring the system away from disintegration, i.e., would reverse the trajectory towards death. Note that the definition is provided for a continuous case. Organisms can rarely jump from a null satisfaction of a function to a full satisfaction, so it is convenient to include the rate of change of the satisfaction of the function in the normative field. Also, the continuous case makes the discontinuous case straightforward (unlike the reverse). But there is an additional reason to characterize normativity

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[13] Note that we have chosen to express the normative field in negative terms. The reason not to put it in positive terms like "constant parametric change to bring the system into a viable region" is that it might not be possible to guarantee that such a viable region exists for some processes; there is no safe harbor, no completely stable region to find refuge, but constant, sometimes cyclic, risk or precariousness that needs to be, on average, continuously compensated for. We illustrate the case with a variation of our model at the end of the next subsection.

as a rate of change. If I haven't eaten for some time and I am approaching the starvation viability boundary, I don't have to eat everything right now, I can slowly start eating provided that I keep that food intake constant for some time. In other words: there is no *normative pressure* to satisfy the need, fully, right now, but only to gradually satisfy it before it is too late. Thus the definition of the norm as a "minimum constant change." Otherwise there would be no possible normative judgment until the very last infinitesimal time right before the system reaches an irreversible path to death. We can illustrate this with a minimal model.

A Minimal Model of (Mal)functioning

Before we move into a definition of function and the different types of dysfunctioning, let me explain and adapt the minimal model of a metabolic normative field provided in Barandiaran and Egbert (2014).[14] We can simplify the metabolism of a cell to a single variable that captures the metabolic activity of the cell (as a raw concentration of metabolites) or take as a reference proxy the concentration of one of the central metabolites of the minimal network [A] and compute the dynamic presupposition or dependence on the intake of environmental matter and energy source [F]. Figure 2a displays the bifurcation diagram of the system for different values of [F]. A bifurcation diagram takes a parameter, in our case [F], and studies the dynamic tendency of a systemic variable [A] as a parametric function of [F]. When [F] is low (below 4 approximately), the diagram shows a single stable equilibrium point at [A] = 0. This means that the spontaneous tendency of metabolite concentration [A], vertical downward arrows, is to decay until the death state is reached at [A] = 0 equilibrium point. When [F] is larger, two additional equilibria appear: a stable equilibrium on top (curved solid line) and an unstable equilibrium (bottom dashed curved line).

The higher the value of [A], the "fatter" the system (the farther away from starvation). The lower the value, the "thinner" (or closer to starvation), until it simply disappears or dies when [A] = 0.[15] The higher the value of [F] to the right, the more food is available to feed the metabolic system. For fixed rates of [F], the tendency of [A] is illustrated with upwards or downwards arrows. So, for example, if the amount of metabolites is very high, [A] = 10, but the amount of available food is very low, with [F] = 2 (position **p** at the top left corner in Fig. 2a), the system will decay until it reaches attractor [A] = 0. As the amount of available food increases, another stable equilibrium appears. If the system is in point **q** (the system is "fat") the concentration of metabolites [A] will decrease and stabilize at the stable equilibrium point. If the system is "mean," not too thin, not too fat, (position **r**) the constant presence of food will make the system "fatten" until the stable equilibrium is met. If the system is very "lean" (position **s**) then [F] = 7 is not sufficient to bring the system to any living stable equilibrium and it dies at [A] = 0.

These tendencies make it possible to distinguish three different regions of the viability space within the bifurcation diagram (see Fig. 2b). The *viable region*, light gray at the top-right side, is the region in which, provided a constant supply of food [F], the system would remain viable, that is, safe and away from a decaying tendency. The *precarious region*, mid-gray space at the top-left side of Fig. 2b, is the region in which the system is still alive but will tend to die of hunger *unless* the supply of food [F] increases at the right pace (eventually, on our example, leading to the viable region[16]). Finally, a *terminal region* can be distinguished (dark-gray space at the bottom of Fig. 2b): the system is still alive but it will eventually die. No matter how much we increase [F], it is already too late to recover, and the system will inevitably disintegrate at [A] = 0.

We can now introduce the concept of normative field in our example (see Fig. 2c). The *normative field* for a process or trait is the constant parametric variation, at each point of its relational space with other traits or variables of the system, that is required to bring the system away from disintegration. It captures the dynamic presupposition that a trait (or part of a system) holds with the rest of the system (represented by the control parameter). On our simple example, the normative field of [F] in relation to [A] is the change of [F] required for [A] to avoid the terminal region (and its consequent death).[17] As we stated before, a *trait operates normatively (or functions properly) when its operations positively correlate with*

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[14] For more detailed and realistic minimal models of early metabolism that share qualitative properties with this model see Barandiaran and Egbert (2014) and Piedrafita et al. (2010, 2012). Similar dynamics can also be found in real empirical models of metabolic pathways (Mulukutla et al. 2014).

[15] The system will most probably die much before [A] = 0 and deadly boundaries rarely map with essential variables reaching 0 (for a similar but more sophisticated model of cell death, see Himeoka et al. 2024). In this simplest case a minimum production of [A] is surely necessary if, for example, the membrane is to be repaired at a sufficiently rapid pace so as to compensate for membrane molecule decay or to make it grow. If this rate is not met the membrane disintegrates or bursts and the system dies. For simplicity, however, we will equate [A] = 0 with the system's disintegration and death.

[16] Note, however, that it is possible that the viable region never exists if the system is burst with a concentration of A that is lower than the stable equilibrium line. In this case the whole viability space would be precarious, and the system would have to oscillate between increasing and decreasing [F] to remain alive.

[17] Note that it might often be the case that the normative field requires that a parameter be held constant, which, in turn, might require a continuous activity of the system. For instance, keeping [F] constant might require actively seeking food in the environment and actively transporting it inside the system.

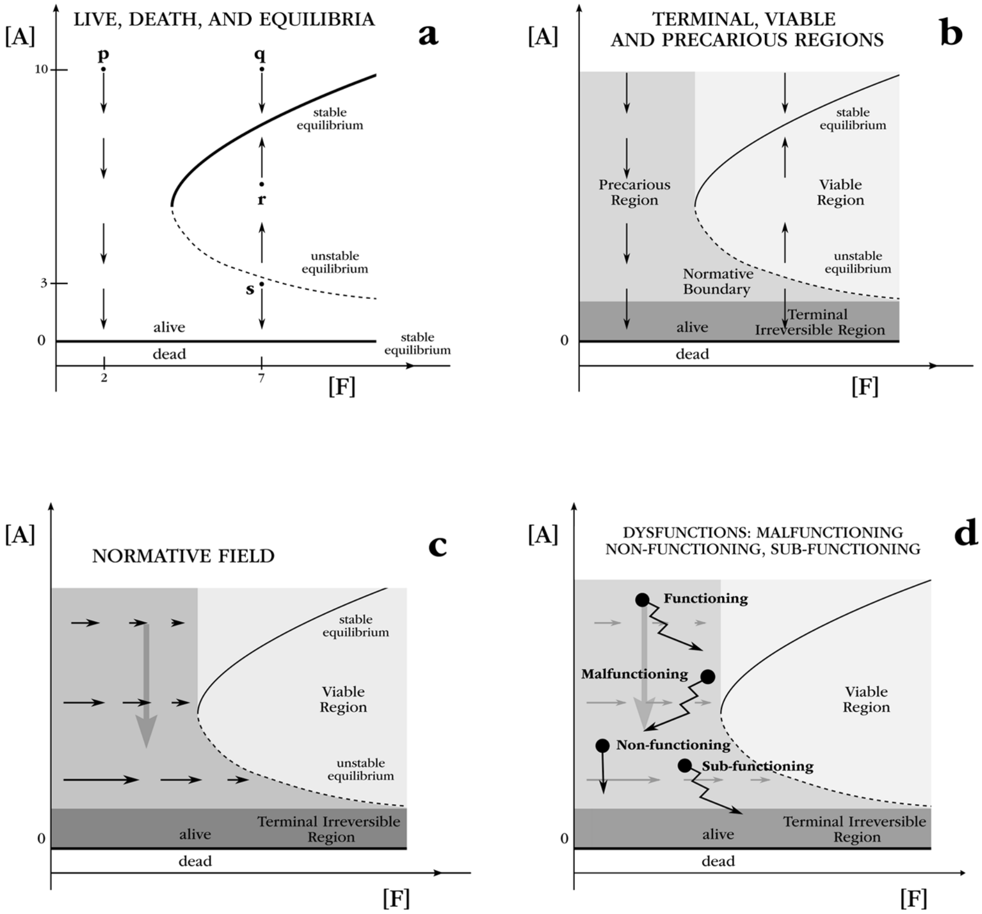

Fig. 2 Bifurcation diagram of a system depicting the incoming food concentration [F] on the x-axis and the amount of internal metabolite concentration [A] on the y-axis. Subfigure **a** depicts the tendency of the system to two stable equilibria (solid lines), the death state at [A] = 0, and the viable state (top curved line); an unstable equilibrium is depicted with a dashed line. Tendencies of [A] are depicted with vertical arrows, with a constant supply of [F] the system at point r moves to the stable living or viable equilibrium, while departing from s it evolves to [A] = 0 and dies. Subfigure **b** displays a partition of the state space into Viable, Precarious, and Terminal regions derived from the tendencies of [A]. Subfigure **c** depicts the normative field as the positive change of [F] that is necessary at each point of the precarious region to avoid death. Subfigure **d** represents 4 different types of trajectories within the viability space: functioning or functional increase of [F] positively correlated with the normative field, malfunctioning modulation of [F] that is not correlated with the normative field and will eventually lead to death; nonfunctioning trajectories also lead to death by inactivity and subfunctioning trajectories are positively correlated with the normative field (pushing [F] to increase) but fail to save the life of the organism (see text for more details)

the normative field. So, for instance, the sensorimotor system of a bacterium operates normatively if it makes the bacterium moves up the food [F] gradient on the environment at the rate necessary to bring and maintain [A] within the viable region. Note that in our example [F] can be interpreted as an "external" variable (the concentration of food available in the environment understood as a boundary condition controlled by the organism's motility) or as a "relational" variable (food intake controlled by membrane permeability, gates, or pumps). But [F] in this model can perfectly be substituted by any "internal" variable (e.g., supply of oxygen to cells, heart rate, etc.) that is controlled by an internal regulatory process.

That we are here picturing stable equilibria does not mean that they are to be expected in nature. In fact, there is no reason to assume that any intrinsic (nonregulated) process is necessarily robust or viable in itself. All known forms or life are continuously regulated, and have developed and evolved to be so. What is to be expected is that only the system as a whole is viable (that is, including all regulatory processes) in open contrast with Moreno and Mossio's conceptual distinction between a stable constitutive closure and a second regulatory one (2015, pp. 33–36). To illustrate this unstable nature we can add a new viability boundary and a new terminal region to our minimal example. It is easily conceivable that there is, together with the bottom boundary, a top boundary of viability so that if the system "eats" too much it can burst (or destroy its viability by other means). Now, if this top boundary is sufficiently low, it leads to a situation where there is no purely viable region. As a result, the system is forced to oscillate between eating too much and too little, always within a precarious region, alternatively risking, ceteris paribus, between either bursting or starving.

Types of Dysfunction: Malfunction, Subfunction, and Nonfunction

According to the normative field approach, we can distinguish three senses of dysfunctionality (see Fig. 2d). *Subfunctional* operations are those that positively correlate with the normative field but quantitatively fail to match the required speed. *Malfunctional* operations are those that do not positively correlate with the normative field, either because they negatively correlate with it or because they don't correlate at all (e.g., the trait is randomly operating). Finally, *nonfunctional* traits either don't operate at all or operate with null effect on the normative field (due to some suboperation of the trait of which the malfunctioning is predicated[18]). It is important to note that not all nonfunctioning traits are dysfunctional, they are only dysfunctional when they *have* to operate and they don't[19] (or when they are dynamically presupposed to do so and they can't).

Consider the case of temperature regulation. A trait could operate in a *functional* manner increasing or decreasing temperature correctly (increasing it at the right pace when needed, decreasing at the right speed when demanded). It can *subfunction*, operating in the right direction but at insufficient speed (increasing temperature when required but too slowly and/or decreasing it when appropriate but at a slower rate than needed). It can also *malfunction*, by operating against the norm (increasing temperature when it needs to be decreased and/or decreasing it when needs to increase). Or it could simply *not function* or fail to function at all when needed (no increase/decrease of temperature is triggered when so needed). Note that the dual-order approach does not distinguish between these three types of dysfunctionality, thus producing a terminological mismatch. Most cases of what SMM call malfunction are here covered by cases of subfunctioning and nonfunctioning, whereas the specificity of what we called malfunctioning is not covered by the dual-order approach.

(Dys)functional Attribution

There are however new questions that are opened by the normative field approach and demand further development. An open question is what I shall call *dysfunctional attribution* (already advanced in Christensen and Bickhard 2002).

So far the normative field approach permits naturalizing *why* something can be said to be dysfunctioning (normative characterization) and *what* is dysfunctioning (normative identification). But the kind of dynamic functional analysis we have provided here is still incomplete. We can identify *what* is the normative function that is not being satisfied to the required degree (dysfunctioning), but dysfunctional attribution requires something else. The supply of [F] is malfunctioning, but is the membrane's intake capacity impaired? Or is the sensorimotor system too slow climbing the [F] gradient? Or is the waste product concentration [W] saturating the system and precluding F intake? Surely all this can be investigated, but such an investigation might well require moving beyond pure dynamical analysis and getting resources from mechanistic explanations (on the one hand) and/or also systemic relationships that can reveal non-decomposable emergent functional properties that complicate (dys)functional attribution.

Other proponents of an organizational approach to normative functionality have taken a systemic approach to the problem of functional attribution:

> if a system is autonomous it will be composed of a network of interdependent processes, and we can understand dysfunction in terms of these interdependencies. If the heart stops beating then there will be a cascade of failures as physiological processes that depend on fluid transport cease to function, leading to the death of the organism. The dysfunction here is systemic—a property of the pattern of network dependencies—and as such not attributable to the heart in isolation. If an alternative mechanism for fluid transport appears, such as an artificial heart, the dysfunction goes away. Again, these network dependencies can be analyzed quite independently of what functions "belong" to the various parts. (Christensen 2012, p. 106)

This is all that Christensen devotes to dysfunctionality and it is difficult to extract a full characterization from this passage. However, since dysfunctions are, in this view, systemic properties, it remains unclear whether they can be directly attributed to specific parts or traits. In the heart example, if the dysfunction disappears as soon as an alternative mechanism is introduced, Christensen seems to rule out the possibility of trait-level dysfunction attribution. It remains an open question how to interpret statements such as "an artificial pacemaker needs to be recharged because the heart is dysfunctional."

Although norms emerge out of systemic and holistic organizations, failure to comply with the norms might still

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[18] Note that the system's partition on functional (and dysfunctional) attribution is not trivial here.

[19] In our case, if the system is within its viable region and [F] starts to decrease, the processes underlying food intake need not be dysfunctional unless or until the system enters the precarious region and action needs to be taken.

be identified and attributed—at least in some cases—to specific parts, processes, or traits. We can expand on the metabolic example used to illustrate the normative field approach to sketch how dysfunctional attribution might work. Let us add another trait, U, which represents the substrate uptake mechanism responsible for importing external nutrients (e.g., food molecules) into the system. This trait directly influences the availability of key substrates (F) required for downstream metabolic processes. If U fails to operate at a rate that matches the demands prescribed by the normative field, the system cannot maintain the required concentration of core metabolites ([A]), which is essential for its viability. Thus, U's operation is critical for providing the material input needed to sustain the system's internal processes. The same goes for an additional trait: the behaving system. No matter how high the uptake rate is, there also has to be enough [F] in the environment for the system to maintain itself. We are thus left with a simple system composed of two component traits that jointly contribute to the presence of substrate F, which in turn is necessary to produce A, which is itself necessary for producing and sustaining the system.

If a system is moving towards a terminal region (e.g., metabolic levels dropping below a critical threshold), the normative field specifies that [A] should increase at a given rate. If the system is failing to provide such an increase, we might wonder which component is dysfunctional: the substrate uptake mechanism (U) or behavior-generating mechanisms (or a combination of both). To pinpoint dysfunction, we can analyze how the system back-propagates effects to causes. It is possible to systematically simulate changes in each trait to determine whether modifying its operation alone suffices to meet normative demands. Traits, however, cannot vary arbitrarily. Empirical and mechanistic constraints, such as physical saturation limits, structure, or friction can restrict how far a parameter can potentially be adjusted. To account for this, the framework should incorporate local mechanistic feasibility ranges, within which each trait could realistically operate, and also systemic organizational presuppositions that might further constraint the feasibility range (e.g., uptake rates that run much faster than the secretion mechanisms that expel the waste product that would be produced at that maximum uptake rate). This backtracking within ranges would deliver answers to question such as: Is the concentration of [F] in the environment sufficient to fuel metabolism, and U too slow up-taking it? Or is U, instead, operating at its local mechanistic maximum and within dynamic presupposition limits, and the cell is failing to navigate the environment to reach required [F] levels?

If a trait, such as U, does not meet its normative requirement within feasible ranges, the framework moves to a deeper level of analysis, and so on recursively. For example, if uptake (U) is impaired because an inhibitor blocks the channels, the absence of a supportive enzyme (S) that neutralizes the inhibitor becomes the underlying cause. To attribute dysfunctionality to specific traits (or a combination of or coordination between them) this systemic backtracking should continue iteratively, identifying the network of dependencies until a feasible intervention is found that, within local mechanistic and systemic presupposed ranges, identifies the restoring local function that is not taking place and can thus be claimed to be "responsible" for the systemic dysfunction.[20]

A possible argument against the normative field approach's capacity to account for functional attribution is that compensations for dysfunctioning would preclude dysfunction attribution.[21] The normative function X is being satisfied (by the compensatory activity of a part of the system over the failure of another); thus, the argument goes, it would be impossible to start attributing dysfunction anywhere, since the approach is blind to the dysfunction itself taking place. But dynamic presuppositions imply that, in physiological terms, compensations have a cost on the viability of the system, and thus can be traced by the solution to the functional attribution problem explained above. Two medical cases might serve to illustrate this point.

When one kidney suffers loss or damage, the remaining kidney compensates by undergoing hypertrophy and hyperfiltration, increasing its workload to maintain overall renal function. This compensation allows the body to maintain normal filtration rates in the midterm. So, the argument against the normative field approach goes, compensation neutralizes the dysfunction (blood is being filtered at the appropriate rate) and it is not possible to claim that the damaged kidney is dysfunctioning. However, prolonged hyperfiltration strains the nephrons, leading to glomerular sclerosis (scarring of kidney filtration units), which, over time, reduces the kidney's ability to filter blood effectively, affecting the viability of the organism. The whole organism presupposes the existence of two kidneys with a specific filtration rate, and the internal organization of a single kidney, although it can potentially compensate for the damage to the

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[20] Crucially, this approach could also distinguish between dysfunction identification chains (or networks) and causal attribution (and potential solutions). While a process like U is identified as dysfunctional because it fails to meet its normative demands, the root cause might lie elsewhere—such as the absence of S. Thus, U is identified as the locus of malfunction (and not the behavioral system), but responsibility for the dysfunction is attributed to S, and the solution lies in restoring S (or removing inhibitors by other means). These back-propagations of dysfunctions can involve several steps in a complex dysfunctional chain or network that could be further caused by one or more identifiable sources.

[21] I thank an anonymous reviewer for pointing this out.

other, will eventually suffer from over-effort. This is one way in which organizational presuppositions are manifested, and it makes it possible to claim that one of the kidneys is dysfunctional "despite" the fact that the renal function is being satisfied by the compensatory activity of the other kidney. This is but one manifestation of organizational presuppositions. The physiological gap left by a diminished kidney, the symmetric distribution (between both kidneys) of veins and arteries, and of ureter, and so on, are others. Altogether they make it possible to identify a dysfunctioning part, without reference to evolutionary history, and without active compensations precluding dysfunctional attribution.

Similarly, when a ligament, such as the anterior cruciate ligament (ACL), is torn, the stability of the knee joint is compromised. To compensate, the surrounding muscles (e.g., quadriceps and hamstrings) adapt by increasing their activity to stabilize the joint during movement. While this muscular compensation can temporarily restore function, it alters the biomechanics of the joint, leading to abnormal stress distribution on the cartilage. Over time, this uneven wear accelerates cartilage degradation, increasing the risk of osteoarthritis, thus affecting viability. Again, the function can be preserved for some time, compensations are effective, but it is the dynamic presupposition of the rest of the body's posture and muscle distribution, and so on, and the way these presuppositions impact overall viability that makes it possible to identify the dysfunction and to characterize it as such.

Discussion and Conclusion

Norms Without Orders

The normative field approach can accommodate the types of malfunction that the dual-order approach excludes: (1) Cases of malfunctioning within a specific self-maintaining regime are perfectly possible. The graduality of the normative field makes it possible for a trait to function, yet to do so at a pace that doesn't match the required speed. The membrane can fail to regulate the inflow of F at the required concentration (e.g., because another molecule is binding to it), and it is thus possible to say that the membrane is malfunctioning. There is no need to appeal to second-order norms or changes or regimes. (2) Regulations (not only constitutive processes) can be said to malfunction. In fact, in our minimal model it is the parametric modulation (that primarily refers to regulations) that is predicated of malfunctioning, while the "constitutive" order provides for the norms that need to be satisfied. In addition, the normative field approach can also account for switches of regimes: for example, a switch of metabolic pathways is just a shift to another dimension of the viability space and the normative field simply increases its dimensionality. The normative field approach is thus simpler and more parsimonious than SMM's approach.

Evolution functions in a tinkering manner so it will often be the case that a trait operates at different orders and functions: sometimes co-defining a set of normative fields (or dynamic presuppositions), sometimes satisfying them. The dual-order approach assumes and requires a dual separation between constitutive and regulatory closures. For instance, Moreno and Mossio claim,

> By definition, therefore, regulatory constraints are different (and complementary) with respect to constitutive ones: they do not contribute to the maintenance of closure in stable conditions (while constitutive ones do) but, when closure is being disrupted, they govern the transition towards its re-establishment (while constitutive ones do not). (Moreno and Mossio 2015, p. 33)

But, in biological systems the basic order is always "broken," there is nothing like a constitutive closure that is intrinsically stable. Does it mean, then, that basic processes are always malfunctioning? Or, instead, that constitutive processes dynamically presuppose regulations as much as they presuppose inflow of reactants, substrate concentration, pressure, or temperature?

Preserving the concept of regulation and malfunctioning only to the combination of (a) the interplay between constitutive and "regulatory" orders, and (b) the shifts between regimes, risks leaving most cases of scientific usage of the term "regulation" out of place. In fact, most of the diversity and complexity of biological processes occurs at the order of regulatory networks, from genetic to metabolic to physiological to nervous. As a raw data, in a typical eukaryotic cell there are two orders of magnitude more catalysts than there are metabolites: "A typical eukaryotic cell has the capacity to make about 30,000 different proteins, which catalyze thousands of different reactions involving many hundreds of metabolites, most shared by more than one 'pathway'" (Cox and Nelson 2004, p. 561). Most regulations are not regulations of constitutive metabolic processes, but regulations over regulations. This is the case of allosteric and hormonal regulations over enzymes that, in turn, regulate metabolic pathways.

So, despite the local mechanistic distinguishability of enzymes from metabolites in terms of molecular origin, folding complexity, or reactive potentials, when studied dynamically what the decoupling makes possible is an enormous increase in functional dimensionality but not a clear-cut ontological distinction between orders and regime changes. From the point of view of functionality, the system is seen as a network of interdependent processes, none of which in isolation can be said to operate functionally out of the multidimensional normative field defined by the rest of the network. It is often possible, and convenient, to distinguish between two networks (metabolic and regulatory, physiological and hormonal, etc.) and connections between elements of the network, but the system ultimately flattens out in terms of dynamic presuppositions, that is, in terms of normativity (albeit other explanatory or ontological distinction might perfectly be made). Moreover, even at the cellular scale, metabolic regulation is not (only) a top-down, enzyme-dominated process. It is a dynamic network where enzymes and metabolites are intimately intertwined. Metabolites exert significant control over enzyme activity through mechanisms like allosteric regulation, creating mixed metabolic and enzymatic networks where there is no clear separation between "regulators" and "regulated" (Gutteridge et al. 2007; Reznik et al. 2017; Euler 2022).

However, it is still possible to be a dualist on organizational orders (acknowledging genuine ontological differences between first- and second-order closure) but a monist regarding norms. The normative field approach presented here is perfectly compatible with the distinction between constitutive and regulatory orders (as conceptualized by the SMM approach) but conceives of norms as emerging holistically and as being satisfied by traits or processes without a dual-order separation between types of norms.[22]

The Organizational Approach, Normative Fields, and their Relationship with Other Theories

A new set of open questions involves the full potential and limitations that the concept of field and viability space holds for theorizing biological systems. The notion of a field can be expanded to embrace more complex dynamic and topological properties. In particular the role of the normative field (and that of the terminal region) can, under some circumstances, be interchangeable or appear deeply intertwined. Some malfunctions or illnesses might reveal themselves more like a shrinking of the viable or precarious regions by increasing the terminal region than as a failure to positively correlate with the normative field. In a sense, some maladies and illnesses might be better conceived as reducing the viability space (and the consequent autonomy of the organism) than as a direct failure to contribute to self-maintenance (Canguilhem 1966; see Etxeberria 2020 for a detailed contemporary analysis).

Within the framework of the normative field and state-space characterization of function, it remains to be seen how the present account fits within the broader framework to teleology developed by McShea (2012). His hierarchical "field theory" defends how seemingly teleological behavior—persistence and plasticity in biological systems—emerges from the influence of a broader, stable, upper-level structure that directs the behavior of a contained system without determining it fully, like a bacteria navigating within a concentration gradient. Upper-directing containment need not be physical but can be conceptualized (and here is a potential continuity with the normative field approach) as a state-space dynamic containment. There are, however, important differences between the organizational approach and McShea. Most notably: (a) McShea takes a rather epistemological stance instead of the stronger, intrinsic, and ontological take of the autonomous organizational approach; (b) for this last approach system and field are codetermined and co-specified whereas the upper-directedness approach can be said to establish a strong independence of the containing system over the contained one; and (c) finally, McShea does not address the role of organizational self-maintenance and normativity for the characterization of teleology. However, despite these (and other) differences, the notion of a normative field (and our definition of dysfunction) can be made compatible and could be taken as complementary to McShea's framework. In particular, the current approach provides precisely the normative dimension to the teleological field: a criterion to identify whether the behaving system within the upper field (and the margin of freedom or variability it enjoys) is acting correctly or making a mistake.[23]

We can now also revisit dispositional accounts of function and see how the normative field approach might be able to contribute to this family of approaches: precisely by providing the normative ground that they have often been claimed to lack. In general, it would be possible to consider organizational approaches as a subclass (albeit a very special one) of dispositional accounts (Cummins 1975; Mills and Beatty 1979; Bigelow and Pargetter 1987) since there is room to interpret that functions contribute to the goal of the system to maintain itself. Moreover, the normative field approach shares with dispositional accounts, such as that of Bigelow and Pargetter (1987), the view that functions must be conceptualized as forward looking or disposed to specific future effects. The normative field needs to run future (or alternative) virtualities in order to characterize (dys)functioning of a specific trait or process. Similarly, the context

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[22] Conflict between normative levels can indeed happen but they demand the emergence of new levels of autonomy (multicellular, sensorimotor, social, etc.). See Barandiaran and Moreno (2006), Barandiaran (2008,2017), or Di Paolo et al. (2017) for the emergence of sensorimotor or cognitive autonomy from biological organization; and García and Barandiaran (2025) for detailed discussion regarding mental health.

[23] I am grateful to an anonymous reviewer, Tiago Rama, and Alejandro Fábregas, for pointing out McShea's work, which I was unaware of prior to the original submission of this manuscript.

of systemic presuppositions, that is essential for functional characterization and attribution, could also be translated to dispositions.[24]

A possible objection raised against defining functions in relation to self-maintenance is that beneficial effects that might contribute to self-maintenance "by chance" could be considered functional.[25] However, to be functional the operation of a trait must *systemically* contribute to the self-maintenance of an organism, in a manner that is dynamically presupposed by the rest of the traits of the organism. This rules out most problematic cases of chance contribution to self-maintenance. Nevertheless, one of the main advantages of the organization approach is that when a random mutation or developmental variation has taken place it can be said to be functional as defined above. On their being functional, there is no distinction between a "random," "new," or "inherent" capacity of a system and those historically selected for (see Newman 2023). The origin might be chance, but it is the effect and the way in which the variation of a trait fits into the network of self-maintaining processes and presuppositions that makes it functional or dysfunctional.

At the beginning of this article we outlined some general objections to alternative biostatistical and the selected-effects theories of (dys)function. The organizational account of function avoids the risk of circularity that selected-effects and biostatistical theories might suffer, by presupposing the function that will next be selected or spread in the population. It does so by grounding functional explanations in the system's viability and the trait's contribution to the maintenance of the system, independently of the trait's evolutionary history or populational prevalence. By making explicit how a trait contributes to self-maintenance, the organizational account provides an explanation of why it might be selected and gain prevalence. The causal contribution of self-maintenance to fitness is straightforward and provides a naturalized account of function before selection has taken place, while explaining why it has taken place. This is connected with the problem of novel functions. If an evolutionarily new trait contributes to self-maintenance in a manner that is dynamically presupposed by the rest of the system, and positively correlates with the normative field, it is a normatively functional trait. If the systemic effect of a genetic mutation, a developmental trajectory, an inherent system's property, or a learned behavior contributes faster, or more accurately, or increasing the viability conditions of a system, then it becomes functional.

So, what is the role of evolution and its relationship with the organizational approach? On the one hand, evolution provides forms of supra-individual organizations to which the organizational approach can also be applied (Saborido et al. 2011), like life cycle, lineages, populations, and so on. But, most notably, together with inherent self-organized, developmental, and ecological processes (and entangled with them), evolutionary dynamics provide a means to explain how all these dynamic presuppositions and coordinations come together. Evolutionary theory (and generalized selected-effects theories) provides an explanation of *how* is it possible for a system to be organized in a functional manner, but does not characterize *what* makes them normative.

Naturalizing (Dys)function Through the Normative Field Approach

The normative field approach to biological function provides an operational bridge between philosophical accounts of normative function and widespread scientific, engineering, and medical practice. In particular, it does so through dynamic and control theory modeling in systems biology (Iglesias and Ingalls 2009; Hannon and Ruth 2014) and, more specifically, in metabolic modeling where the objective function is commonly considered to be biomass growth (Yasemi and Jolicoeur 2021); which is the equivalent, albeit with some philosophical implications, of avoiding decay.

Metabolic dynamic analysis, and similar approaches in complex physiological dynamical systems, has been applied to the study of disease (Voit 2009), with viability constraints being defined by biomarkers; some of which are familiar to all of us through the health indicators and their thresholds shown in clinical analyses (such as blood or urine tests). Although population-level or statistical averages are often used as proxies to distinguish the normal from the pathological, the normative judgment of a biomarker's state and evolution is, as acknowledged, ultimately individual—centered on the organism, its specific conditions (age, environment, etc.), personal trajectory, and autonomous organization (Voit 2009; Vo and Trinh 2024).

Modeling the full viability space and normative field of any living system is extraordinarily complex and may not be feasible, due to empirical, experimental, and computational limitations that grow exponentially. However, this can be achieved in simplified artificial life models (Egbert and Pérez-Mercader 2018; Barandiaran and Egbert 2014; Beer et al. 2024), synthetic biology models (Pušnik et al. 2019), and toy models of cellular viability (Himeoka et al. 2024). The role of philosophy is to characterize what norms are—regardless of how empirically difficult it may be to

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[24] It is on the nature of dispositions and powers and their relationship with complex emergent properties that differences might arise between organizational accounts and some dispositionalist metaphysical commitments. But these discussions are out of the scope of this article.

[25] Rabbits with brown eyes are unconsciously given more food than blue eyed ones by the farmer, because brown eyes remind her of an old girlfriend. Is the function of brown eyes to unconsciously seduce the farmer?

identify normative functions in living systems—provided that this characterization is done in an *in principle* naturalized manner, without invoking extra-natural principles and while offering operational bridges with scientific theories. The normative field approach meets this requirement and establishes strong ties with current biological research and medical practice.

The Nature of Norms

Perhaps the underlying metaphysical assumption that is at the core of the two-level view of (mal)functioning defended by SMM is that norms are somewhat *causally actual*, or operate as mechanisms.[26] This is notably the case when they state that, "the norms generated by closure *are blind* with respect to the distinction between these two types of effects […] Hence, the distinction between (well-)functions and malfunctions requires an additional set of norms*"* (Moreno and Mossio 2015, p. 82; italics added). Malfunctioning and normativity are thus conceived as a conflict between causes: first-level and second-level norms. The whole enterprise here is to save functionality from epiphenomenalism. In fact, this is argued to be the strong property of systemic and organizational accounts of function over etiological ones (Christensen and Bickhard 2002; Mossio et al. 2009; Garson 2016).

But there is an additional possibility. Norms can be understood as *transcendental*, in the Kantian tradition followed by contemporary discourse ethics theoreticians like Habermas (1985) or Apel (1984). From an operational perspective, norms appear as conditions of possibility for the organism's very existence—within an extended present (or across scales of extended presents) that sustain the organization anchoring those norms. This does not exactly render norms epiphenomenal; rather, it suggests an explanation that cuts across both epi- and sub-phenomenal levels. Normativity could be said to be epiphenomenal in the sense that it offers a higher-order normative description of system operations—descriptions that different parts of the system may or may not conform to, to varying degrees. At the same time, it is sub-phenomenal (and thus transcendental in the Kantian sense) insofar as it refers to modes of functioning among parts that constitute the very conditions of possibility for the system's ongoing existence.[27] For the system to exist as an observable entity here and now, the normative description must already have been satisfied.

Functions are explanatory without being *efficiently* causal. Organisms display a deep causal-material entanglement that is not nomologically reducible to statistical magnitudes (like pressure, weight, etc.), but can, under certain circumstances, be subsumed under functional descriptions. It is the actual fulfillment of a function that has causal significance, not the function as such. It is because the parts fulfill functions (and because their doing so enables the existence of both themselves and the organism as a whole) that functional descriptions are explanatory. The virtual (counterfactual or relational) account of normative (mal)functioning enabled by the normative field approach captures this specific nature of normativity.[28] By modeling these norms as fields of minimally required parametric changes that pull the system away from terminal regions (where it would otherwise be lost towards disintegration), the approach seeks to provide a conceptual, empirical, and mathematical grounding for normative judgments without presupposing stable reference classes, selected effects, or statistical normality. According to this view, it is ultimately the autonomy of each living organization (in its open and interdependent singularity and becoming) that marks the horizon of normative judgments.

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[26] Moreno, personal communication (2009).

[27] Yet, this transcendental dimension remains fully immanent, emerging from within the physical and organizational dynamics of the system itself, rather than being imposed from outside.

[28] In this sense the normative field approach might be connected to a modal conception of norms in analytic tradition (Nanay 2010), and it is also possible to draw connections to transcendental empiricism (Deleuze 1995) and the notion of virtuality inherited from Bergson and Simondon. This is, however, not the place to elaborate on these connections.

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